

1                   **APPARATUS AND METHOD FOR PROTECTING**  
2                   **FLOATING ROOF TANKS**  
3                   **FROM THE EFFECTS OF LIGHTNING STRIKES**

4  
5                   FIELD OF THE INVENTION

6  
7       The present invention relates generally to liquid storage tanks having roofs  
8       that float on the surface of the stored liquid and particularly to an apparatus  
9       and method for protecting storage tanks having floating roofs from the effects  
10      of lightning strikes.

11  
12                  BACKGROUND OF THE INVENTION

13  
14      Lightning strikes that hit equipment and storage or process vessels containing  
15      flammable materials can cause devastating incidents at refineries, bulk plants,  
16      processing sites and other facilities. In recent years, several incidents have  
17      occurred where lightning has struck facilities storing or handling flammable  
18      substances, which resulted in explosions and fires. Substantial monetary loss  
19      due to damage to the facility and loss of product and significant environmental  
20      damage may occur as a result of the effects of a lightning strike.

21  
22      Floating roof tanks are widely used to store volatile petroleum-based liquids  
23      and limit the quantity of product evaporative emissions that may escape to the  
24      environment. Such tanks may be configured either as internal floating-roof  
25      tanks or as external floating-roof tanks. In each configuration, the floating roof  
26      is designed to remain in contact with the product liquid surface and cover  
27      almost the entire surface of the product. A small annular area between the  
28      outermost rim of the floating roof and the inside surface of the tank shell is  
29      covered by a seal attached to the rim of the floating roof. There are many  
30      types of seals available for the annular space and are selected based on the  
31      owner's preference, the type of product, and emissions reduction

1 requirements. In many cases today, tanks have two seals, one of which is  
2 used to reduce the emissions from the tank to very low levels.

3  
4 Seals for floating roofs within storage tanks can assume a variety of different  
5 configurations. One such arrangement is shown in U.S. Patent No. 4,308,968.  
6 That arrangement includes two different seals, the first being a primary seal  
7 and the second being a backup or secondary seal. This sealing arrangement  
8 utilizes vapor barriers in combination with flexible metal plates and wiper  
9 blades. The vapor barriers, which are common in many floating roof seals,  
10 comprise one or more layers of fabric which are generally impermeable to  
11 vapors from the liquid product stored in the tank.

12  
13 One type of floating roof seal which has been found to be quite effective is the  
14 shoe seal. Shoe seals employ a shoe in the form of a series of joined-together  
15 plates which are disposed against the inner wall of the tank and which are  
16 supported by the outer rim of the floating roof. A vapor barrier extending  
17 between the outer rim and the shoe provides an effective barrier to vapors  
18 from the liquid product in the tank, inasmuch as the lower portion of the shoe  
19 extends into the product.

20  
21 Examples of shoe seals are provided by U.S. Patent. No. 2,981,438;  
22 U.S. Patent No. 3,167,206; and U.S. Patent No. 4,130,217. In  
23 U.S. Patent No. 2,981,438, the sealing mechanism is provided with a  
24 combination weatherhood and wax trough. The shoe is forced against the  
25 inner tank wall by spring-loaded pistons mounted within the outer rim of the  
26 floating roof. In 3,167,206, the shoe is suspended from the outer rim of the  
27 floating roof by a pivoting hanger structure designed to force the shoe against  
28 the inner tank wall. In U.S. Patent No. 4,130,217, various different members  
29 including springs are employed to maintain the shoe against the inner tank  
30 wall.

1 Sometimes, these sealing systems have, as an option, included a shunt  
2 located above the seals to provide an electrical path for static or lightning  
3 induced electricity from the floating roof to the tank wall so that any arcing  
4 resulting from the flow of electricity occurs near the shunt and away from the  
5 potentially ignitable vapors stored below the seals. Such a system is disclosed  
6 in U.S. Patent Nos. 5,529,200 and 5,667,091, which are incorporated by  
7 reference herein. Another system that is similarly configured is disclosed in  
8 U.S. Patent No. 4,371,090.

9  
10 The following are excerpts from the current Chapter 6 of NFPA 780-2000,  
11 Standard for the Installation of Lightning Protection Systems, on floating roof  
12 tanks. These excerpts demonstrate the need for the improved method and  
13 apparatus of the present invention.

14  
15 **"6.4.1.2 Floating Roof Tanks**

16  
17 (a) **General.** Fires have occurred when lightning has struck  
18 the rims of open-top floating roof tanks where the roofs  
19 were quite high and the contents volatile. Similar  
20 above-the-seal fires have occurred when direct lightning  
21 strokes to the rims of floating roof tanks have ignited  
22 flammable vapors within the open shells. These have  
23 occurred where roofs were low. The resulting seal fires  
24 have been at small leakage points in the seal. An  
25 effective defense against ignition by a direct stroke is a  
26 tight seal.

27  
28 Fires have also occurred in the seal space of open-top  
29 floating roof tanks as a result of discharges caused by  
30 lightning. These have occurred most frequently in tanks  
31 having floating roofs and seals with vapor spaces below  
32 the flexible membranes. Similar vapor spaces will be  
33 formed where tanks are fitted with secondary seals in  
34 compliance with environmental regulations. Ignition can  
35 be from a direct stroke or from the sudden discharge of  
36 an induced (bound) charge on the floating roof, released  
37 when the charge on a cloud discharges to ground or to  
38 another cloud.

39  
40 (b) **Protection.** Where floating roofs utilize hangers located  
41 within a vapor space, the roof shall be electrically bonded

1 to the shoes of the seal through the most direct electrical  
2 path at intervals not greater than 10 ft (3 m) on the  
3 circumference of the tank. These shunts shall consist of  
4 flexible Type 302, 28-gauge [1/64 in. x 2 in. (0.4 mm x  
5 51 mm)] wide stainless steel straps or the equivalent in  
6 current-carrying capacity and corrosion resistance. The  
7 metallic shoe shall be maintained in contact with the shell  
8 and without openings (such as corrosion holes) through  
9 the shoe. Tanks without a vapor space at the seal shall  
10 not require shunts at the seal. Where metallic weather  
11 shields cover the seal, they shall maintain contact with  
12 the shell.

13  
14 Where a floating roof is equipped with both primary and  
15 secondary seals, the space between the two seals could  
16 contain a vapor-air mixture within the flammable range;  
17 therefore, if the design of such a seal system  
18 incorporates electrically conductive materials and a spark  
19 gap exists within that space or could be created by roof  
20 movement, shunts shall be installed so that they directly  
21 contact the tank shell above the secondary seal. The  
22 shunts shall be spaced at intervals not greater than 10 ft  
23 (3 m) and shall be constructed so that metallic contact is  
24 maintained between the floating roof and the tank shell in  
25 all operational positions of the floating roof."  
26

27 It has been found that the shunts and shoes used in present installations do  
28 not adequately protect the floating roof storage tanks from the effects of a  
29 lightning strike. It was assumed that they had sufficient contact to the outer  
30 tank wall for conducting such a discharge; however, it has been found in  
31 some cases that the measured resistance between the shoe and outer tank  
32 wall was in the order of millions of ohms. This high resistance connection  
33 point would cause an ignition source or arcing that could ignite the flammable  
34 vapors in the primary seal, or at the secondary seal along the rim of the  
35 floating roof. American Petroleum Institute's collection of 44 years of member  
36 company data reveals 65 large aboveground storage tank fires caused by  
37 lightning, 61% of the cases evaluated (API Publication 2021A,  
38 Interim Study-Prevention and Suppression of Fires in Large Aboveground  
39 Atmospheric Storage Tanks, July 1998).

1 NFPA 77-2000 (Recommended Practice on Static Electricity) states that  
2 bonding of equipment or parts with less than one megohm in resistance  
3 should be sufficient to dissipate the small charges that would occur from static  
4 sources. Conductive bonding for static discharge is typically less than  
5 10 ohms resistance. However, a lightning stroke discharge current is orders of  
6 magnitude larger than a static electricity discharge and requires a much lower  
7 bonding resistance. API RP 2003-1998 (Protection Against Ignitions Arising  
8 Out of Static, Lightning, and Stray Currents) suggests that for lightning, the  
9 bonding resistance needs to be significantly lower, no more than a few ohms.  
10 NFPA 780-2000 (Standard for the Installation of Lightning Protection  
11 Systems) requires bonding conductors be sized to be a minimum of 26,240  
12 circular-mil cross-section copper — much less than one ohm resistance for a  
13 typically short bonding distance.

14  
15 Among other factors, the present invention is based on our discovery that  
16 removing the shunts above the seals would prevent the arcing from occurring  
17 and thus prevent a rim fire. Additionally, by adding a corrosion resistant  
18 bonding strap and welding or bolting this strap to the bottom of the shoe  
19 assembly below the product level and to the lower portion of the floating roof  
20 pontoon assembly also below the product level would provide the most direct  
21 electrical path to earth for the lightning stroke current to flow and would be in  
22 an environment that is the most oxygen deficient. The use of the submerged  
23 bonding strap or shunt of the present invention would eliminate the currently  
24 used “above the seal” bonding strap and protect the tank and its combustible  
25 contents. This type of submerged bond would have less than one ohm  
26 resistance, and if any arcing occurred, it would be in a total liquid phase with  
27 no oxygen to support combustion. Furthermore, the lightning secondary  
28 effects (e.g., the induced “bound” charge as described in NFPA 780-2000)  
29 would be minimized as an added benefit.

## SUMMARY OF THE INVENTION

The present invention provides a method of protecting a floating roof tank from the effects of a lightning strike comprising the step of placing an electrically conductive bonding strap at one end into electrical contact with an inner wall of the tank below liquid level in the tank and connecting a second end of the bonding strap to the floating roof below liquid level, the bonding strap being of a length to minimize its self inductance, so as to provide a preferred electrically efficient path for conducting electrical current through an oxygen deficient environment.

The present invention also provides an improvement In a liquid storage tank having an inner tank wall and a floating roof, the improvement which comprises means for establishing electrical communication between the inner tank wall and the floating roof, said means being located below the liquid level and being configured to have minimum self inductance, so as to provide a preferred path for dissipating electrical current through an oxygen deficient environment in the storage tank.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a portion of an oil storage tank having a floating roof and a seal between the outer rim of the floating roof and the inner tank wall.

FIG. 2 is a side view of a shoe seal according to one embodiment of the present invention.

## DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a storage tank 10 having a floating roof 12 disposed therein. The floating roof 12 floats on top of a liquid product such as oil or other hydrocarbon products stored within the tank 10.

To prevent hydrocarbon vapors from escaping into the atmosphere from the space between an outer rim 14 of the floating roof 12 and an inner tank wall 16, a seal 18 is provided. The seal 18 extends between the outer rim 14 of the floating roof and the inner tank wall 16 around the circumference of the floating roof 12, and acts as a barrier to hydrocarbon vapors. The seal 18 must be capable of movement up and down the inner tank wall 16 while maintaining a sealing relationship therewith, so that the floating roof 12 may rise or fall with varying quantities of liquid product stored in the tank 10.

The seal 18 may be of the shoe type in which a series of plates joined together and extending around the circumference of the floating roof 12 form a shoe which is mounted on the outer rim 14 of the floating roof 12. As described hereafter, shoe seals scissors hanger assemblies for hanging the shoe on the outer rim 14 in combination with resilient elements which force the shoe outwardly from the outer rim 14 of the floating roof 12 and into engagement with the inner tank wall 16.

FIG. 2 depicts an embodiment of a shoe seal 20 that may be used in accordance with the present invention. FIG. 2 depicts a portion of the storage tank 10 of FIG. 1 including the inner tank wall 16 and a portion of the floating roof 12 including the outer rim 14. The roof 12 floats on oil or other liquid product 42 stored within the tank 10.

The shoe seal 20 includes a shoe 22 comprised of a series of metal plates. In addition to the shoe 22, the shoe seal 20 includes a plurality of scissors hanger assemblies 30 which mount the shoe 22 on the outer rim 14 in a

1 manner permitting a substantial amount of movement of the shoe 22 relative  
2 to the outer rim 14. This permits the shoe 22 to be maintained in contact with  
3 the inner tank wall 16 in the presence of varying space between the outer rim  
4 14 and the inner tank wall 16 about the circumference of the floating roof 12  
5 and irregularities in the surface of the inner tank wall 16. The scissors hanger  
6 assemblies 30 are mounted in spaced apart fashion along the shoe 22. The  
7 scissors hanger assemblies 30 are coupled to the shoe 22 by bolting and are  
8 mounted on the outer rim 14 of the floating roof 12 by bolting.

9  
10 FIG. 2 is a side view of the shoe seal 20 which shows a liquid product 42  
11 within the tank 10. The liquid product 42 supports the floating roof 12. As  
12 shown in FIG. 2, the scissors hanger assembly 30 includes an elongated plate  
13 44 having an upper end 46 pivotally coupled to a shoe clip 48. The shoe clip  
14 48 is bolted to the shoe 22. The elongated plate 44 extends downwardly and  
15 outwardly from the shoe clip 48 and the shoe 22 and terminates at a lower  
16 end 50 thereof which contacts the floating roof 12. The scissors hanger  
17 assembly 30 also includes a pair of elongated bars 52 which are pivotally  
18 coupled at upper ends 56 thereof to a rim clip 58. The rim clip 58 is bolted to  
19 the outer rim 14 of the floating roof. The elongated bars 52 extend  
20 downwardly and outwardly from the rim clip 58 and the floating roof 12. Only  
21 the elongated bar 52 is seen in FIG. 2, inasmuch as the opposite elongated  
22 bar 54 is disposed there behind on the other side of the elongated plate 44  
23 therefrom. The elongated bars 52 and have intermediate portions 60 which  
24 are pivotally coupled to an intermediate portion 62 of the elongated plate 44.  
25 A vapor barrier 36 is mounted so as to extend between the shoe 22 and the  
26 outer rim 14. Such vapor barrier 36 is provided by a length of vapor  
27 impermeable fabric.

28  
29 The scissors hanger assemblies 30 mount or hang the shoe 22 on the floating  
30 roof 12 in a manner which permits considerable lateral movement of the shoe  
31 22 relative to the floating roof 12. This enables the shoe seal 20 to



1 accommodate substantial variations in the space between the inner tank wall  
2 16 and the floating roof 12 around the circumference of the floating roof 12.

3

4 As shown in FIG. 2, the shoe 22 extends down into the liquid product 42. This  
5 is one of the features of shoe seals which make them effective. The vapor  
6 barrier 36 seals the space between the shoe 22 and the outer rim 14 of the  
7 floating roof 12, while at the same time flexing as necessary to permit lateral  
8 movement of the shoe 22 relative to the floating roof 12. Because the lower  
9 end of the shoe 22 is immersed in the liquid product 42, vapors from the liquid  
10 product 42 within the space between the shoe 22 and the floating roof 12 are  
11 trapped by the vapor barrier 36. The shoe 22 is normally in contact with the  
12 inner tank wall 16 so that no vapors from the liquid product 42 can pass there  
13 between. However, in instances where the shoe 22 pulls away from the inner  
14 tank wall 16 to form a small space there between, vapors from the liquid  
15 product 42 escaping through the small space are negligible. A shoe seal of  
16 this kind is described in greater detail in U.S. Patent Nos. 5,103,992 and  
17 5,667,091, which are incorporated by reference herein.

18

19 Sometimes, shoe seals have as an option included a shunt located above the  
20 seals to provide an electrical path for static or lightning induced electricity from  
21 the floating roof to the tank wall so that any arcing resulting from the flow of  
22 electricity occurs near the shunt and away from the potentially ignitable  
23 vapors stored below the seals. Such systems are disclosed in  
24 U.S. Patent Nos. 5,529,200 and 5,667,091. With reference to FIG.2, a shunt,  
25 not shown, in resilient contact with the inner tank wall 16 would be installed  
26 above the vapor barrier 36 by attachment to an upper end of the floating roof  
27 12 above the product level to provide an electrical path for static or lightning  
28 induced electricity from the floating roof 12 to the inner tank wall 16. This is  
29 shown in FIG. 2 of U.S. Patent No. 5,667,091.

30

31 Further with reference to FIG. 2, bonding strap (or shunt) 70 is mounted so as  
32 to extend between a lower end of shoe 22 and a lower end of floating roof 12

1 to establish electrical communication there between below the level of liquid  
2 product 42 stored in the tank 10. Bonding strap 70 could be connected by  
3 bolting, welding, clipping or other methods known to the skilled artisan. The  
4 bonding strap 70 is immersed in the liquid stored in the tank, for example, by  
5 being connected at the bottom of the shoe and tank roof pontoon assembly to  
6 provide the preferred path for lightning stroke current in the most  
7 oxygen-deficient zone of the scissor and shoe assembly. Consequently, there  
8 would no longer be a need for the presently used "above the seal" bonding  
9 strap or shunt.

10

11 Bonding strap 70 may be made of any electrically conductive material such as  
12 stainless steel, copper, tinned-copper, or bronze (formed as a flexible braid or  
13 as a flexible, ribbon-shaped strap). The material for the bonding strap is  
14 preferably corrosion resistant. Stainless steel is preferred. What we have  
15 termed a bonding strap is sometimes referred to as a grounding strap or a  
16 shunt. The present invention contemplates the use of any means to provide a  
17 path for electrical communication between the inner tank wall 16 and the  
18 floating roof 12, and any technique used to minimize its electrical self  
19 inductance or to reduce its electrical high-frequency resistance to lightning  
20 surge currents.

21

22 The dimensional characteristics of bonding strap 70 are an important  
23 consideration in providing protection against the effect of lightning strikes,  
24 which produce current of up to 200,000 amperes. As such, the bonding strap  
25 70 should be sized to be of a length to minimize its self inductance, i.e., it  
26 should be no longer than necessary to bridge the gap between the shoe and  
27 the floating roof considering the practical necessity for it to adapt to shell  
28 irregularities. In the context of the shoe assembly exemplified herein, the  
29 length of the strap would be as required to permit the "scissor" spring  
30 assembly to be bridged and to allow for normal travel of the scissor-spring  
31 assembly centering function. This adaptation would lengthen the bonding  
32 strap 70 by no more than the allowed seal tolerances (typically 4 inches). An

1 adaptation is also considered that keeps the bonding strap taut by use of an  
2 integral or external spring mechanism. The width of the strap gives the strap a  
3 large surface area and minimizes the self inductance and high-frequency  
4 resistance of the strap connection, and this is more important for carrying  
5 lightning surge current with minimum rise in voltage across the strap. This  
6 feature, combined with the many parallel paths across the numerous scissor  
7 assemblies, would minimize sparking and if sparking should occur, it will be in  
8 a very "rich" oxygen-deficient zone.

9  
10 The bonding strap 70 should also be configured for good physical durability.  
11 The cross-sectional area would typically be at least 0.031 square inches to  
12 conform to NFPA 780 requirements. It should preferably be at least 1 inch  
13 wide to keep the strap's self inductance high-frequency resistance to a  
14 reasonably low value. One preferred example would be to use a standard  
15 1-inch wide braided strap which would be approximately 4 AWG  
16 (American Wire Gauge) size. This is far larger in cross-section than required  
17 in the NFPA 780 requirements for the present "above the seal" bonding shunt.

18  
19 The bonding straps 70 are located at any desired interval around the  
20 circumference of the tank and are preferably located at intervals of 10 feet  
21 around the circumference of the tank to conform to current NFPA  
22 requirements. This interval could be adjusted to be in conformance with future  
23 NFPA standard requirements or recommendations.

24  
25 There is no requirement for tank grounding or earthing, because what is more  
26 important for lightning protection is proper bonding of metallic parts to  
27 eliminate or minimize arcing. The ANSI consensus standard on the subject,  
28 NFPA 780-2000 (Standard for the Installation of Lightning Protection  
29 Systems), only requires one of the following for tank grounding:

- 30  
31 1) Connection, without insulating joints, to a grounded metallic piping  
32 system.

1 2) Vertical cylindrical tanks 6 m (20 ft), or greater, in diameter be resting on  
2 concrete or earth, or tanks 15 m (50 ft), or greater, in diameter be resting  
3 on bituminous pavement.

4

5 3) Tanks be bonded to ground by at least two 2.4 m (8 ft) long ground rods,  
6 or other acceptable ground terminals, at maximum 30 m (100 ft)  
7 intervals along the perimeter of the tank.

8

9 Modifications and alternative embodiments of the invention will be apparent to  
10 those skilled in the art in view of the foregoing description. Accordingly, this  
11 description is to be construed as illustrative only and is for the purpose of  
12 teaching those skilled in the art the best mode of carrying out the invention.  
13 The details of the structure may be varied substantially without departing from  
14 the spirit of the invention, and the exclusive use of all modifications which are  
15 within the scope of the appended claims is reserved.